TFL 1 inventory audit

Introduction

An inventory is conducted by the licensee of each Tree Farm Licence (TFL) in British Columbia every 10 to 30 years, using standards and procedures that are approved by the Ministry of Forests. Regular updates are undertaken to reflect changes in the timber volume due to growth and to depletions from harvesting and natural causes.

This report presents the results of an inventory audit performed within TFL 1. Managed by Skeena Cellulose Inc., TFL 1 is centred around the municipality of Terrace. North of Terrace, it reaches to the Nass Valley, including the Ishkheenickh and Kiteen drainages; to the east, it encompasses the Copper River valley; and to the west it includes the area south of the Skeena River known as the Whitebottom. Most of the licence area is located on the west side of the Kalum Valley extending north of Terrace. TFL 1 covers approximately 609 000 hectares.

Purpose of the audit and application of the results

It is often asked, "How accurate is the current inventory?" To answer this important question, the Ministry of Forests has developed an inventory audit methodology specifically designed to test the overall accuracy of estimates of the total standing volume in each timber supply area.

This inventory audit methodology entails sampling three primary components of the inventory: mature forests, immature forests, and non-forest areas.

The objective of the inventory audit program is to help identify TFLs or TSAs where the forest inventory needs attention. Enough samples are taken to ensure statistically reliable results for the TSA or TFL as a whole.

The amount of data collected, however, is not sufficient to make statistically reliable conclusions about specific areas or tree species. For example, any overall differences highlighted by the audit could result from problems with one tree species, from part of the land base (such as high elevation rather than lower elevation areas), from one age group of forest stands, or from a combination of these and other factors. As a consequence, general audit results cannot appropriately be used to adjust information about the forests currently available for timber harvesting since this area constitutes only a portion of the total forested area in the TSA or TFL.

The audits provide information that may be useful to the Chief Forester when determining the allowable annual cut—offering a general assessment of the uncertainty associated with mature timber volumes, immature site index, and the non-forest classification. However, the audit results cannot justifiably be used to make specific adjustments to growth and yield and other information used in timber supply analyses and allowable annual cut determinations.

Methods

Current inventory

There are 35 TFLs in British Columbia, varying in size from approximately 8500 hectares to just over 1 million hectares. Inventories of each TFL are conducted by the licensee through a multistage process. Although the methodology varies within each TFL, all standards must be approved by the Ministry of Forests. New standards currently under development will ensure a consistent minimum standard for all TFLs. Generally, polygons are first delineated from 1:15 000-scale aerial photographs. Photo-interpretation is then used to produce data on a number of attributes for each polygon. These attributes generally include species composition, stand height, age, and crown closure. Timber volume is then estimated indirectly using the photo-interpreted variables and an empirical yield model. Other approaches to volume estimation, approved by the Ministry of Forests, may also be used.

To keep estimates current, inventories are regularly updated to account for forest growth and for depletions due to harvesting, fire, and the impact of insects and disease damage. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visitation, satellite imagery, and aerial photographs may be used to update the inventory for depletions.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands older than 60 years). The inventory audit tests the accuracy of the mature timber volume. The second component tested is immature stands (younger than 60 years but older than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment for these stands. The third component tested is the area classified as non-forest in the inventory, which includes areas such as lakes, gravel pits, and alpine meadows. The audit tests the accuracy of the photo-interpreted classification for this component.

Mature component assessment criteria

To test the mature component of the inventory, the existing inventory's estimate of the mean mature volume per hectare for the TFL (*the inventory volume*), is compared with a new estimate of the mean mature volume per hectare obtained from the audit samples (*the audit volume*). In most TFLs the inventory volume is assessed from base yield curves derived from the VDYP yield model.

The difference between these two estimates is called the total bias. A test is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TFL.

If the total bias is found to be statistically significant, further analyses may be conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; or
- *model bias:* This is caused by poor prediction from the yield model, which was developed for large areas of the province and was not designed for specific management units.

In most TFLs the analysis used to determine the source of bias uses an estimate of the mean mature volume per hectare for the TFL called *the ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model. The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the inventory classification attributes or the yield model itself.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An airphoto interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably scaled forest cover aerial photograph. Classification accuracy is rated using a point scoring scheme to determine an overall accuracy percentage. The acceptance criteria for this test is 85% or higher.

TFL 1 audit sampling procedures

The TFL 1 sample used updated maps based on the most recent inventory. A list of all polygons identified on these maps was produced and sorted on a number of stand characteristics (site quality, age, and species group). Polygons were systematically selected from this list by a process designed to produce a representative sample of the TFL.

For the mature forested component of the inventory audit, a random sample of 50 forested polygons from the total forested area in the TFL was selected for sampling.

Up to 4 full-measure prism plots and 5 count plots were established within each of the 50 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 200 full-measure and 250 count plots were established. Field data collection and compilation followed Ministry of

Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes produced by the licensee.

For TFL 1 (and for many other TFLs in the province), corresponding polygon-specific base inventory volumes are not available for all audit samples. In these cases, the audit volume is compared with *analysis unit volumes*. These analysis unit volumes are derived from analysis unit yield curves, which are aggregations of the base volume yield curves and are used to predict volume in the timber supply analysis process. Therefore, in situations where base yield curves are not available, *analysis unit volume* replaces *inventory volume* in the standard inventory audit comparisons, and is the basis on which the accuracy of audit volume estimation is assessed.

To be consistent with the utilization standards used by the licensee in the timber supply analysis, audit volumes were compiled for all live trees of 17.5+ cm dbh (except 12.5+ cm dbh where the leading species on the inventory classification was lodgepole pine). The audit volumes represented merchantable volume net of decay, waste, and breakage (as estimated from Ministry of Forests loss factors). Dead potential and veteran trees were not included in the compilation.

The audit volume estimates were then compared to the analysis unit volume estimates to test the validity of the current inventory. A paired comparison *t*-test was used to test for significant differences. The precision of the analysis unit volume estimates – how well each analysis unit volume estimate corresponds to the audit volume estimate on a sample-by-sample basis – was assessed by measuring the statistical correlation. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons was selected for sampling. Up to 6 inventory ground calls were established within each of the 20 sample polygons.

The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. A total of about 120 ground calls were established and data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the immature forested component should be used with caution.

To audit the non-forest component, a random sample of 30 non-forest polygons was selected. Standard Ministry of Forests inventory airphoto classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding airphoto checks.

Inventory audit results

Analysis of mature volumes

Results of the statistical analyses of the inventory audit for mature (greater than 60 years of inventory age) volume for the total forested area are given in Table 1.

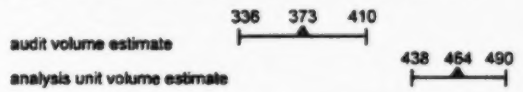
TABLE 1. Statistics for the audit volume and analysis unit volume estimates at 17.5+ cm dbh utilization (except 12.5+ cm dbh for lodgepole pine leading), net decay, waste, and breakage, TFL 1

	Audit Volume Estimate	Analysis Unit Volume Estimate
Number of samples	50	50
Mean (m^3/ha)	373	464
Coefficient of variation (%)	35	20
Standard error	18.5	12.9
Sampling error (%)	10.0	5.6
95% confidence interval (m^3/ha)	336–410	438–490

Correlation coefficient r = -0.004

Ratio of means (audit/analysis unit volume) = 0.80

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of -0.004 for the audit and analysis unit estimates indicates a poor relationship among the individual samples. There is a 91 m^3/ha difference between the mean analysis unit estimate for mature volume (464 m^3/ha) and the audit estimate (373 m^3/ha). A paired-sample *t*-test determined that this difference is statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is -137 to -46 m^3/ha.

Analysis of operable and inoperable volumes

To provide audit results more likely to be applicable to the timber supply planning process, an

approximation was made of the forested areas considered currently available for timber harvesting (operable areas). Any sample with greater than 0% of its area in the net operable land base was considered operable in this analysis. The audit results were post-stratified based on this approximation. The results of the inventory audit for samples in the operable forested areas in the TFL are given in Table 2.

TABLE 2. Statistics for the audit volume and analysis unit volume estimates at 17.5+ cm dbh utilization (except 12.5+ cm dbh utilization for lodgepole pine leading), net decay, waste, and breakage, operable forested areas, TFL 1

	Audit Volume Estimate	Analysis Unit Volume Estimate
Number of samples	37	37
Mean (m^3/ha)	382	470
Coefficient of variation (%)	37	19
Standard error	23.0	15.0
Sampling error (%)	12.2	6.5
95% confidence interval (m^3/ha)	335–428	440–501

Correlation coefficient $r = -0.031$

Ratio of means (audit/inventory) = 0.81

Bar graph representation of 95% confidence intervals (in m^3/ha)

For the 37 samples located within the operable forested area, the mean audit volume is 382 m^3/ha and mean analysis unit volume is 470 m^3/ha. The difference between these two estimates (88 m^3/ha) is statistically significant, 19 times out of 20.

Eleven samples were in inoperable forested areas. This sample size is too small to allow any meaningful comparisons to be made. Because of the high variability and restrictive nature of conclusions associated with this small sample size, volume estimates from inoperable forested areas are not shown.

Analysis of mature inventory using VDYP as the yield model

To provide a more comprehensive review of inventory volume accuracy, further analysis was undertaken. This analysis, described earlier in the report under "Mature component assessment criteria," involved predicting inventory volumes using the Ministry of Forests VDYP yield model and the classification attributes as they exist in the inventory for TFL 1. To simplify the analysis, a utilization limit of 17.5+ cm dbh was applied to all species, and all volumes were estimated net of decay only.

It should be noted that the VDYP yield model was not used by the licensee in the last timber supply analysis and hence was not the yield model used to derive the analysis unit volumes. The results of analysis of the mature (greater than 60 years of age on the inventory) volume for the total forested area, using VDYP as the yield model, are given in Table 3.

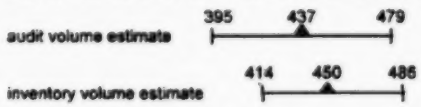
TABLE 3. Statistics for the audit volume and inventory volume (using VDYP) estimates at 17.5+ cm dbh utilization, net decay only, TFL 1

	Audit Volume Estimate	Inventory Volume Estimate
Number of samples	50	50
Mean (m^3/ha)	437	450
Coefficient of variation (%)	34	28
Standard error	20.7	17.8
Sampling error (%)	9.5	7.9
95% confidence interval (m^3/ha)	395–479	414–486

Correlation coefficient $r = 0.347$

Ratio of means (audit/inventory volume) = 0.97

Bar graph representation of 95% confidence intervals (in m^3/ha)



The correlation coefficient of 0.347 for the audit and inventory estimates indicates a moderate relationship among the individual samples. There is a 13 m^3/ha difference between the mean inventory estimate for mature volume using VDYP (450 m^3/ha) and the audit estimate (437 m^3/ha). A paired-sample *t*-test determined that this difference is not statistically significant 19 times out of 20. Similar trends were apparent when the analysis was restricted to operable samples. This analysis indicates that when VDYP is used as the yield model, there appears to be no significant bias in the mature inventory volume for TFL 1.

Analysis of immature inventory classification

Out of 20 stands sampled in the field, the inventory correctly identified site index within ±5 m of the audit site index for 11 stands; the inventory site index was more than 5 m lower than the audit site index for 8 stands, and more than 5 m higher for 1 stand.

Analysis of non-forest inventory classification

Thirty stands classified as non-forest were assessed for accuracy of the inventory. The resulting score was 67%, which does not meet the provincial minimum standard of 85%.

Discussion and conclusions

The objective of the inventory audit in TFL 1 was to assess the overall accuracy of the current inventory. The mature, immature, and non-forest components were tested.

The results of the audit for the mature component of the inventory suggest that the analysis unit volumes have been over-estimated. When the data was post-stratified, a similar bias was observed in the operable forested area. There were some issues around what constituted an operable polygon, but even with a more conservative definition, the trends remained the same.

However, additional analyses that examined the accuracy of the inventory using the VDYP yield model and the current inventory attributes did not show the same volume over-estimation bias that was apparent for the analysis unit volumes in TFL 1. Using VDYP and the current TFL 1 inventory attributes produced statistically acceptable inventory volumes.

Audit results for the immature component of the inventory suggest an acceptable level of accuracy for site index assignment in young stands. However, it should be noted that the low inventory site index assignment in 8 of the sample stands appears to be due to a potential under-estimation of regenerated stand heights.

The audit assessment of the non-forest classification in this TFL indicates that it did not meet provincial standards. Anomalies in the non-forest classification were observed due to poor stratification of height class 1 and 2 forested stands within alpine and snow slide areas. Results indicate that the issue of non-forest classification accuracy in this TFL has no impact on the forested area available for timber harvesting reported in the timber supply analysis.

Glossary

accuracy: A measure of how close an estimate is to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building blocks around which inventory data and other information are organized for use in forest planning models, typically involving specific tree species or type groups that are further defined by site class, geographic location, or similarity of management regimes.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of variation within a population, calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The estimated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship, whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

dead potential trees: Standing or down timber which is estimated to contain at least 50% of its original gross volume in sound wood content.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground-level field procedures designed to provide physical verification of polygon inventory attributes.

free-growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs, or other trees.

inoperable lands: Lands that are unsuited for timber production now and in the foreseeable future because of their topography, inaccessibility, low value of timber stands, or designation for uses incompatible with timber production.

mean: The average value of a set of observations.

polygon: A portion of land area, delineated on mid-scale aerial photographs, of "like" or uniform land cover type.

pre-inventory assessments: Inventory activities to evaluate the existing forest inventory as a basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

public sustained yield units (PSYU): A portion of a TSA; an area of Crown land, usually a natural topographic unit determined by drainage areas, managed for sustained yield by the Crown through the Ministry of Forests. It includes all Crown lands within the currently established boundaries of the unit, and excludes federal lands, provincial parks, experimental forest reserves, gazetted watersheds and tree farm licences.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations.

sampling error: The error attributed to sampling procedures.

significant difference: The results of a statistical test comparing either two or more estimates, or an estimate to a fixed value. If the difference is too large to be attributed to chance, the difference is said to be statistically significant.

site index: An expression of the forest site quality of a stand, at a specified age, based either on the site height, or on the top height, which is a more objective measure.

standard error: An expression of the absolute variability of an estimate.

standard deviation: A measure of the variation of the population.

timber supply analysis: An assessment of future timber supplies over long planning horizons (more than 200 years) by using timber supply models for different scenarios identified in the planning process.

timber supply area (TSA): An area defined by an established pattern of wood flow from management units to the primary timber-using industries.

tree farm licence (TFL): Privately managed Sustained Yield Units; designed to enable owners of Crown-granted forest lands and old temporary tenures or the timber licences which replace them, to combine these with enough unencumbered Crown land to form self-contained sustained yield management units.

variable density yield prediction (VDYP) model: An empirical yield-prediction system for natural stands based on data collected in temporary inventory sample plots (TSPs) and natural, permanent growth sample plots (PSPs). VDYP predicts volume (net decay) and diameters at four utilization levels using stand height, age, and density. The aerial approach uses crown closure as the density measure.

veteran trees: Mature living trees which are remnants of an older stand.

For more information

For more information or to obtain other inventory audit reports, contact: Director, Resources Inventory Branch, B.C. Ministry of Forests, 722 Johnson Street, Victoria, B.C., Canada V8W 3E7 Phone 250-387-1314 Fax 250-387-5999. Visit our web site at http://www.for.gov.bc.ca/resinv/homepage.htm

June 1997

TFL 1 Inventory Audit

Technical Report

Table of Contents

Introduction 1
Purpose of the audit and application of the results 1
Methods 1
- Current inventory 1
- Inventory audit procedures 2
- Mature component assessment criteria 2
- Immature component assessment criteria 3
- Non-forest component assessment criteria 3

TFL 1 audit sampling procedures 4
Inventory audit results 5
- Analysis of mature volumes 5
- Analysis of operable and inoperable volumes 6
- Analysis of mature inventory using VDYP as the yield model 8
- Analysis of mature species classification 16
- Analysis of immature inventory classification 17
- Analysis of non-forest inventory classification 18

Discussion and conclusions 18
References 19
Appendices 19
Glossary 25

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To keep estimates current, inventories are regularly updated to account for forest growth, and for depletions due to harvesting, fire losses, and the impact of insects and disease. Empirical yield models, such as the Ministry of Forests Variable Density Yield Prediction (VDYP) computer model, are used to update the inventory for forest growth. Field visits, satellite imagery and aerial photographs may be used to update the inventory for depletions.

Inventory audit procedures

The inventory audit tests three components of the current inventory. The first component is the mature forested areas (forest stands greater than 60 years old). The inventory audit tests the accuracy of the mature timber volume and also examines the species classification accuracy for the mature forested areas. The second component tested is immature stands (younger than 60 years but older than the silvicultural classification of free growing). The audit tests the accuracy of the site growth potential (site index) assignment and the accuracy of the species classification for these stands. The third component tested is the area classified as non-forest in the inventory, which includes areas such as lakes, gravel pits, and alpine meadows. The audit tests the accuracy of the photo-interpreted classification for this component.

Mature component assessment criteria

To test the mature component of the inventory, the existing inventory's estimate of the mean mature volume per hectare for the TFL (the *inventory volume*), is compared with a new estimate of the mean mature volume per hectare obtained from the audit samples (the *audit volume*). In most TFLs the inventory volume is assessed from base yield curves derived from the VDYP yield model.

The difference between these two estimates is called the total bias. A paired sample *t*-test (Walpole 1974) is conducted on this bias to determine if it is statistically significant. This test establishes whether there are detectable differences between the audit volume estimate and the inventory volume estimate, for the total forested area of the TFL.

If the total bias is found to be statistically significant, further analyses are conducted to determine if the specific source of bias within the inventory is one of the following:

- *classification bias:* This is caused by incorrectly estimating the polygon attributes; and/or
- *model bias:* This is caused by poor prediction from the yield model.

In most TFLs the analysis to determine the source of bias uses an estimate of the mean mature volume per hectare for the TFL called the *ground attribute volume*. This is calculated from audit sample attributes (stock and stand table estimates of species composition and stocking, and ground-based averages of top height and age), along with crown closure taken from the original map label, using the yield prediction model.

The difference between the ground attribute volume estimate and the audit volume estimate approximates the bias associated with the yield model. The difference between the audit volume estimate and the inventory volume estimate not accounted for by the model bias approximates the bias associated with the inventory classification attributes. Once the source is identified, further analyses may be done on the inventory classification attributes or the yield model itself.

Note that the analyses using ground attribute volume can only approximate the model and classification bias. Model and classification bias are usually confounded to some degree and are difficult to separate. For example, there is model error inherently associated with the inventory attributes since inventory heights are updated or projected. There may also be errors related to stand dynamics that are influenced by the length of time between the original inventory and the audit (the projection period). In addition, model error may exist as a result of a bias associated with the plots used to fit the yield prediction model. Analyses using ground attribute volume cannot be used to precisely identify the source of bias in an inventory, however, they may be useful to indicate potential areas for further investigation.

The species classification accuracy for the mature component is also examined. Species composition is generally determined by visually estimating percent crown cover by species from aerial photographs. For analysis and general reporting purposes these species types are then combined into 17 broad aggregations of species groupings called growth type groups. Growth type groups are often the primary basis for species type stratification used in the timber supply analysis process. The accuracy of the species composition attribute can be judged by comparing how often the inventory growth type group classification agrees with the audit sample classification. A statistical measure called the *K* statistic is used to evaluate this level of agreement (Cohen 1960). The *K* statistic compares the observed level of agreement (the proportion of growth type group matches) with the expected level of agreement. A "high level of agreement" for the *K* statistic is based on a 5% significance level. It is assumed that the audit samples represent the entire polygon and that a ground based species composition derived from a volume summary is compatible with a photo based species estimate.

Immature component assessment criteria

Accuracy of the inventory classification for immature stands is tested by examining the site index assignment. Since the immature forest stand site index provides an estimate of site productivity, its accuracy affects the projection of long-term harvest levels.

Data gathered is examined to determine how closely the audit and inventory site indices match for individual samples, and to explore potential trends.

The species classification accuracy for the immature component of the inventory is also examined. Using the same approach that was outlined in the mature component section, a *K* statistic is used to determine the level of agreement in the growth type group classification between the audit and the inventory.

Non-forest component assessment criteria

The audit test for the non-forest component of the inventory assesses the accuracy of the non-forest classification assignment. An airphoto interpreter certified by the Ministry of Forests compares the non-forest inventory classification to a suitably-scaled forest cover aerial photograph. Classification accuracy is rated from a point scoring scheme to

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Up to four full-measure prism plots, and five count plots, were established within each of the 50 sample polygons. The plots were located systematically, using a square grid and a random start point. The grid interval distance varied with polygon size. To reduce sample costs for large or irregular polygons, only a randomly selected portion of the polygon was sampled. A total of about 200 full-measure and 250 count plots were established. Field data collection and compilation followed Ministry of Forests cruising and cruise compilation procedures. The objective was to obtain audit volumes that were comparable (in terms of utilization standards and merchantability definitions) to the inventory volumes that are produced by the licensee.

In the case of TFL 1, and many other TFLs in the province, polygon-specific inventory volumes are not available to correspond to all audit samples. Across much of the inventory area, the polygons are aggregated into large analysis units and volume estimates are computed using empirical yield equations specific to each analysis unit. For each of the inventory audit samples, the licensee provided the appropriate analysis unit volume. As a result, in TFL 1, the *analysis unit volumes* replaced inventory volumes in the standard inventory audit comparisons. To be consistent with the utilization standards used by the licensee in the timber supply analysis, audit volumes were compiled for all live trees of 17.5+ cm dbh (except 12.5+ cm dbh where the leading species on the inventory classification was lodgepole pine). The audit volumes represented merchantable volume net of decay, waste, and breakage (as estimated from Ministry of Forests loss factors). Dead potential and veteran trees were not included in the compilation. When considering the audit results, it should be noted that there are some differences between the utilization standards applied in the audit and those used operationally.

The audit volume estimates were then compared to the analysis unit volume estimates to test the validity of the current inventory. A paired sample *t*-test was used to test for a significant difference. The precision of the inventory volume estimates – how well the inventory volume estimate corresponds to the audit volume estimate on a sample by sample basis – were assessed by measuring their statistical correlation. The ratio of mean audit volume to mean inventory volume, and the confidence interval for this ratio was also calculated. A *K* statistic was calculated to determine if the observed level of growth type group agreement between the inventory and the audit was statistically significant. The data was then post-stratified to detect trends related to the operable and inoperable forested land base distribution of the sampled polygons.

From the immature forested component, a random sample of 20 polygons were selected for sampling. Up to six inventory ground calls were established within each of the 20 sample polygons. The plots were located along a single transect line that was considered representative of the site productivity (site index) of the stand. A total of about 120 ground calls were established. Field data collection followed the standard Ministry of Forests inventory ground call procedures. The location of the sample transect was subjective. Since the magnitude of bias caused by this process is unknown, the reported results and their interpretations for the immature forested component should be used with caution.

Site index was calculated using the site index curves i Freddie (the Ministry of Forests' site index estimation program), using total age (or breast height age where available) and top height. This audit site index was compared with the inventory site index provided by the licensee. As with the mature component, a *K* statistic was used to evaluate the growth type group classification.

For the audit of the non-forest component of the inventory, a random sample of 30 non-forest polygons were selected. Standard Ministry of Forests inventory air photo classification techniques were used to compare the 30 non-forest polygon classification assignments to corresponding air photo checks.

Inventory audit results

Analysis of mature volumes

Results of the statistical analyses of the inventory audit for mature (greater than 60 years of inventory age) volume for the total forested area are given in Table 1.

	Audit Volume Estimate	Analysis Unit Volume Estimate
Number of Samples	50	50
Mean (m^3/ha)	373	464
Coefficient of variation (%)	35	20
Standard error (m^3/ha)	18.5	12.9
Sampling Error (%) at 95% confidence level	10.0	5.6
95% Confidence Interval (m^3/ha)	336–410	438–490

Table 1: Statistics for the audit volume and analysis unit volume estimates at 17.5+ cm dbh utilization (except 12.5+ cm dbh for lodgepole pine leading), net decay, waste, and breakage, TFL 1.

audit volume estimate 336——373——410

analysis unit volume estimate 438——464——490

Table 2: Bar graph representation of 95% confidence intervals in m^3/ha

The correlation coefficient of -0.004 for the audit and analysis unit estimates indicates a poor relationship among the individual samples. There is a 91 m^3/ha difference between the mean analysis unit estimate for mature volume (464 m3/ha) and the audit estimate (373 m^3/ha). A paired-sample t-test determined that this difference is

statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is -137 to -46 m^3/ha.

Figure 1 provides a graphical representation of the total bias of the analysis unit volumes for the mature component of the total forested area of TFL 1. The letter codes on the scatter plots correspond to the growth type groups for the polygons as assigned in the inventory (see Table 3). The correlation coefficient, the ratio and its confidence interval, and the results of the paired-sample *t*-test accompany the graph.

Growth Type Group Letter code	Growth Type Group Species Composition	# of polygons
E	Cw, Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH	1
F	H, HDecid.	9
G	HFd, HL, HPy, HPw, HPl, HCw, HB, HS	32
H	B, BH, BS, BFd, BPw, BPl, BL, BPy, BDecid	5
J	SFd, SL, SPw, SH, SCw, SYc, SB	1
M	PlFd, PlPy, PlL, PlPw, PlS, PlB, PlH, PlCw, PlYc	2

Table 3: Distribution of growth type groups (as assigned by the inventory) for the mature sample polygons.

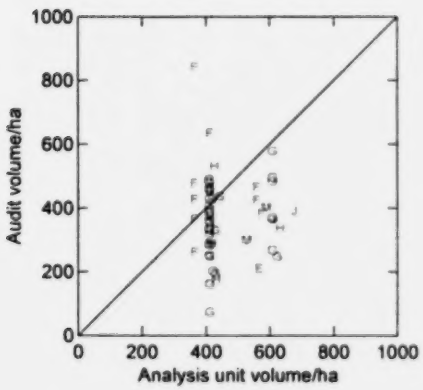

Figure 1: ***Total Bias*** Audit volume versus analysis unit volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=50)

Correlation coefficient: r = -0.004
(p-value* = 0.979)

Mean difference (audit volume -analysis unit volume)
= - 91.19 m^3/ha (p-value* < 0.001)
95% confidence interval for mean difference:
-137 — -46

Ratio of means = 0.80
95% confidence interval for ratio of means:
0.71 — 0.90

** a p-value* ***< 0.05*** *indicates statistical significance (at a 5% significance level)*

Analysis of operable and inoperable volumes

To provide audit results more likely to be applicable to the timber supply planning process, an approximation was made of the forested areas considered currently available for timber harvesting (called *operable* areas). Any sample with greater than 0% of its area in the net operable land base was considered operable in this analysis. The audit results were post-stratified based on this approximation (see Appendices B and C for the operable and inoperable subsets of the mature sample data). The results of the

inventory audit for the operable and inoperable forested areas in the TFL are given in Table 4.

	Operable		Inoperable	
	Audit Volume Estimate	Analysis Unit Volume Estimate	Audit Volume Estimate	Analysis Unit Volume Estimate
Number of Samples	37	37	13	13
Mean (m^3/ha)	382	470	347	446
Coefficient of variation (%)	37	19	29	21
Standard Error (m^3/ha)	23.0	15.0	27.8	26.1
Sampling Error (%) at 95% confidence level	12.2	6.5	17.5	12.8
95% Confidence Interval	335–428	440–501	286–408	389–503

Table 4: Statistics for the audit and analysis unit volume estimates at 17.5+ cm dbh utilization (except 12.5+ cm dbh for lodgepole pine leading), net decay, waste, and breakage for operable and inoperable areas, TFL 1.

Table 5: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area.

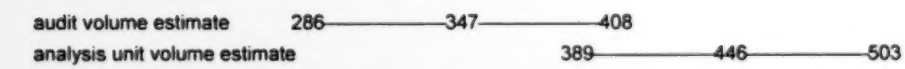

Table 6: Bar graph representation of 95% confidence intervals in m3/ha for the inoperable forested area.

For the 37 samples located within the operable forested area, there is an 88 m^3/ha difference between the mean audit volume (382 m^3/ha) and the mean analysis unit volume (470 m^3/ha). A paired-sample t-test determined that this difference is statistically significant 19 times out of 20. The 95% confidence interval for the mean paired difference is -145 to -32 m^3/ha.

For the thirteen samples located within the inoperable forested area, the mean audit volume was 347 m^3/ha and the corresponding analysis unit volume was 446 m^3/ha. Although the difference was statistically significant, any conclusions regarding the inoperable samples must be viewed with caution due to the limited sample size.

Figures 2 and 3 provide a graphical representation of the total bias in the analysis unit volume estimates for the operable and inoperable forested areas in TFL 1.

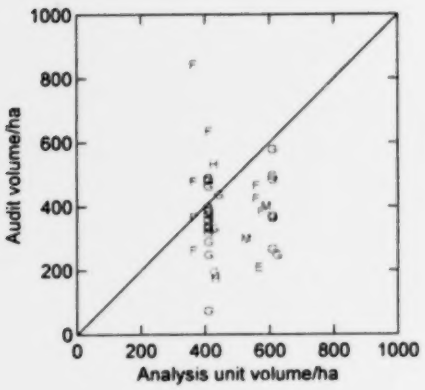

Figure 2: ***Total Bias for the Operable Forested Area*** Audit volume versus analysis unit volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=37)

Correlation coefficient: r = -0.031
(p-value* = 0.854)

Mean difference (audit volume - analysis unit volume)
= - 88.46 m^3/ha (p-value* = 0.003)
95% confidence interval for mean difference:
-145 — -32

Ratio of means = 0.81
95% confidence interval for ratio of means:
0.70 — 0.93

** a p-value **< 0.05** indicates statistical significance (at a 5% significance level)*

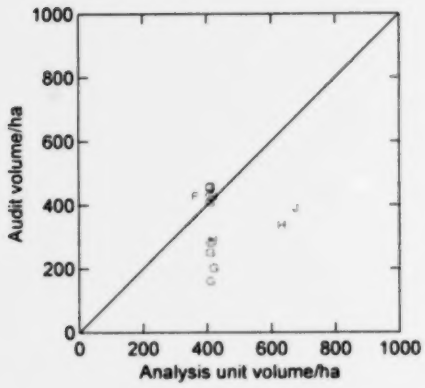

Figure 3: ***Total Bias for the Inoperable Forested Area*** Audit volume versus analysis unit volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=13)

Correlation coefficient: r = 0.035
(p-value* = 0.909)

Mean difference (audit volume - analysis unit volume)
= - 98.95 m^3/ha (p-value* = 0.022)
95% confidence interval for mean difference:
-181 — -17

Ratio of means = 0.78
95% confidence interval for ratio of means:
0.61 ——— 0.94

** a p-value **< 0.05** indicates statistical significance (at a 5% significance level)*

Analysis of mature inventory using VDYP as the yield model

To provide a more comprehensive review of inventory volume accuracy, further analysis was undertaken. This analysis, described earlier in the report under "Mature component assessment criteria", involved predicting inventory volumes using the Ministry of Forests VDYP yield model and the classification attributes as they exist in the inventory for TFL 1. To simplify the analysis, a utilization limit of 17.5+ cm dbh was applied to all species, and all volumes were estimated net of decay only.

It should be noted that the VDYP yield model was not used by the licensee in the last timber supply analysis and hence was not the yield model used to derive the analysis unit volumes. The results of analysis of the mature (greater than 60 years of age on the inventory) volume for the total forested area, using VDYP as the yield model, are given in Table 7.

	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	50	50	50
Mean (m^3/ha)	437	450	450
Coefficient of variation (%)	34	28	31
Standard error (m^3/ha)	20.7	17.8	20.0
Sampling Error (%) at 95% confidence level	9.5	7.9	8.9
95% Confidence Interval (m^3/ha)	395–479	414–486	410–490

Table 7: Statistics for the audit volume, inventory volume (using VDYP), and ground attribute volume estimates at 17.5+ cm dbh utilization, net decay only, TFL 1.

audit volume estimate	395	437	479
inventory volume estimate	414	450	486
ground attribute volume estimate	410	450	490

Table 8: Bar graph representation of 95% confidence intervals in m^3/ha

The calculated correlation coefficient for the audit and inventory volume estimates is 0.347, indicating a moderate relationship among individual samples. There is a 13 m^3/ha difference between the inventory estimate for mature volume using VDYP (450 m^3/ha) and the audit estimate (437 m^3/ha). The sample evidence was insufficient for the paired-sample *t*-test to determine a statistically significant difference between these two estimates. The 95% confidence interval for the mean paired difference is -57 to +31 m^3/ha. For a similar sample, the volume difference would have to be at least 63 m^3/ha for the paired-sample *t*-test to detect a significant difference, 8 out of 10 times.

Although there was no statistically significant difference between the audit estimate and inventory volume estimate from VDYP, the ground attribute volume was calculated from VDYP for general information purposes.

Figure 4 provides a graphical representation of the total bias in the inventory volumes for the mature component of the total forested area of the TFL. Although the total bias was not statistically significant, Figures 5 and 6 provide information on the model bias and the classification bias. Figures 7 and 8 show the relationship between the audit and the inventory for the attributes of height and age respectively.

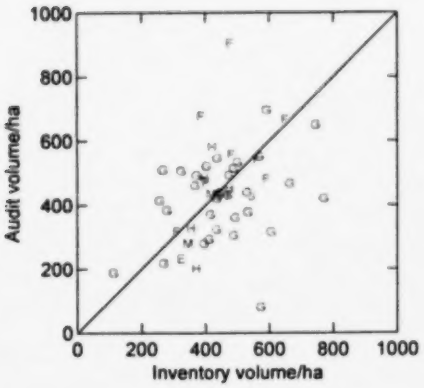

Figure 4: *Total Bias* Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=50)

Correlation coefficient: $r = 0.347$
(p-value* = 0.013)

Mean difference (audit volume - inventory volume) = -13.02 m^3/ha (p-value* = 0.559)
95% confidence interval for mean difference:
-57 — 31

Ratio of means = 0.97
95% confidence interval for ratio of means:
0.87 — 1.07

** a p-value < 0.05 indicates statistical significance (at a 5% significance level)*

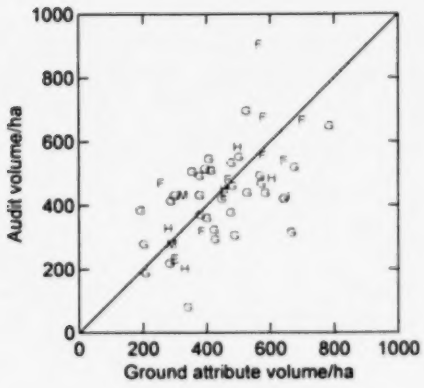

Figure 5: *Model Bias* Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=50)

Correlation coefficient: $r = 0.565$
(p-value < 0.001)

Mean difference (audit volume - ground attribute volume) = -13.20 m^3/ha (p-value = 0.491)
95% confidence interval for mean difference:
-51 — 25

Ratio of means = 0.97
95% confidence interval for ratio of means:
0.89 — 1.05

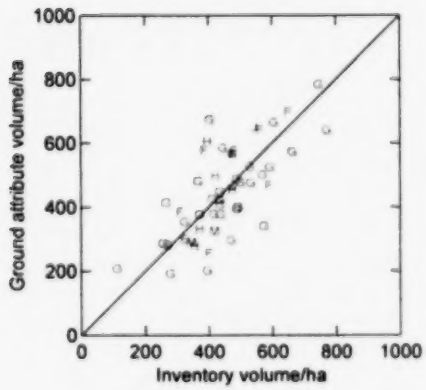

Figure 6: *Classification Bias* Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=50)

Correlation coefficient: $r = 0.704$
(p-value < 0.001)

Mean difference (ground attribute volume - inventory volume) = 0.18 m^3/ha (p-value = 0.990)
95% confidence interval for mean difference:
-29 — 30

Ratio of means = 1.00
95% confidence interval for ratio of means:
0.93 — 1.07

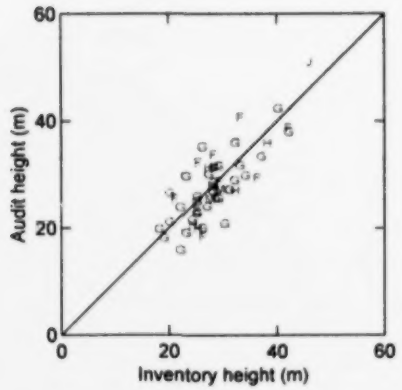

Figure 7: ***Height*** Audit (ground measured) top height versus inventory height, by inventory growth type group. Diagonal line represents a perfect correlation. (n=50)

Correlation coefficient: r = 0.789
(p-value < 0.001)

Mean audit height = 28.13 m
Mean inventory height = 28.60 m

Mean difference (audit height - inventory height) =
-0.47 m (p-value = 0.441)
95% confidence interval for mean difference:
-1.70 — 0.75

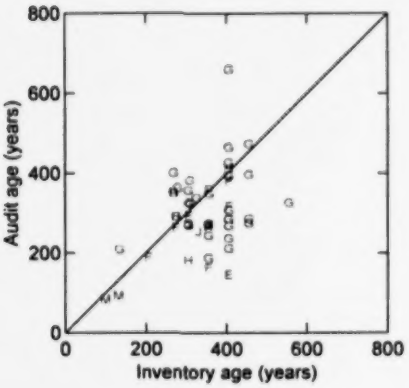

Figure 8: ***Age*** Audit (ground measured) age of top height trees versus inventory age, by inventory growth type group. Diagonal line represents a perfect correlation. (n=50)

Correlation coefficient: r = 0.429
(p-value = 0.002)

Mean audit age = 302 years
Mean inventory age = 343 years

Mean difference (audit age - inventory age) =
-40 years (p-value = 0.006)
95% confidence interval for mean difference:
-69 — -12

When the analysis was restricted to the operable samples, similar trends were apparent. The analysis indicated that when VDYP is used as the yield model, there appears to be no significant bias in the mature inventory volume for TFL 1. The results of analysis of the mature (greater than 60 years of age on the inventory) volume for the operable and inoperable forested area, using VDYP as the yield model, are given in Table 9.

	Operable			Inoperable		
	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate	Audit Volume Estimate	Inventory Volume Estimate	Ground Attribute Volume Estimate
Number of Samples	37	37	37	13	13	13
Mean (m^3/ha)	452	478	468	394	370	398
Coefficient of variation (%)	34	25	28	29	30	41
Standard Error (m^3/ha)	25.4	19.7	21.6	31.8	30.4	44.8
Sampling Error (%) at 95% confidence level	11.4	8.3	9.4	17.6	17.9	24.5
95% Confidence Interval	400–504	438–518	425–512	325–464	304–436	301–496

Table 9: Statistics for the audit, inventory and ground attribute volume estimates (using VDYP as the yield model) at 17.5+ cm dbh utilization for operable and inoperable forested areas in TFL 1.

audit volume estimate	400	452	504
inventory volume estimate	438	478	518
ground attribute volume estimate	425	468	512

Table 10: Bar graph representation of 95% confidence intervals in m^3/ha for the operable forested area.

audit volume estimate	325	394	464
inventory volume estimate	304	370	436
ground attribute volume estimate	301	398	496

Table 11: Bar graph representation of 95% confidence intervals in m^3/ha for the inoperable forested area.

Figures 9 to 11 provide a graphical representation of the total bias, the model bias and the classification bias associated with the inventory volumes (using VDYP as the yield model) for the operable forested area. Figures 12 and 13 show the relationship between the audit and the inventory for the attributes of height and age respectively.

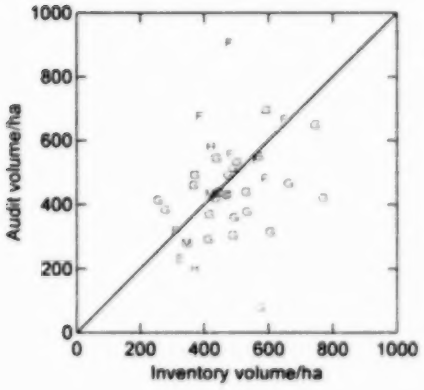

Figure 9: ***Total Bias for the Operable Forested Area*** Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=37)

Correlation coefficient: r = 0.273
(p-value = 0.102)

Mean difference (audit volume - inventory volume)
= -26.21 m^3/ha (p-value = 0.348)
95% confidence interval for mean difference:
-82 — 30

Ratio of means = 0.95
95% confidence interval for ratio of means:
0.83 — 1.06

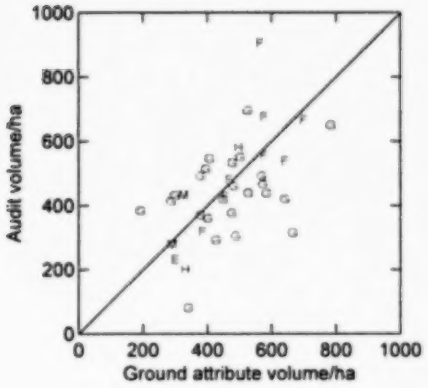

Figure 10: ***Model Bias for the Operable Forested Area*** Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=37)

Correlation coefficient: r = 0.540
(p-value = 0.001)

Mean difference (audit volume - ground attribute volume) = -16.42 m^3/ha (p-value = 0.476)
95% confidence interval for mean difference:
-63 — 30

Ratio of means = 0.96
95% confidence interval for ratio of means:
0.87 — 1.06

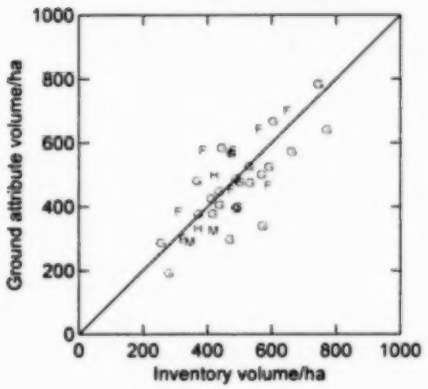

Figure 11: ***Classification Bias for the Operable Forested Area*** Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=37)

Correlation coefficient: r = 0.743
(p-value < 0.001)

Mean difference (ground attribute volume - inventory volume) = -9.78 m^3/ha (p-value = 0.516)
95% confidence interval for mean difference:
-40 — 20

Ratio of means = 0.98
95% confidence interval for ratio of means:
0.92 — 1.04

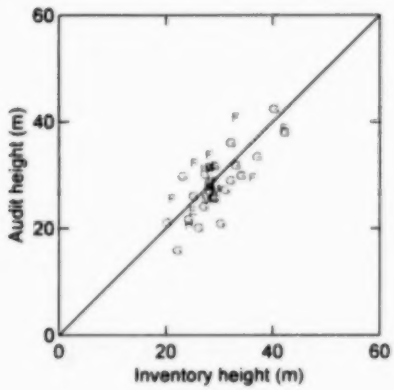

Figure 12: ***Height*** Audit (ground measured) top height versus inventory height, by inventory growth type group. Diagonal line represents a perfect correlation. (n=37)

Correlation coefficient: r = 0.731
(p-value < 0.001)

Mean audit height = 28.74 m
Mean inventory height = 29.28 m

Mean difference (audit height - inventory height) = -0.54 m (p-value = 0.430)
95% confidence interval for mean difference:
-1.92 — 0.84

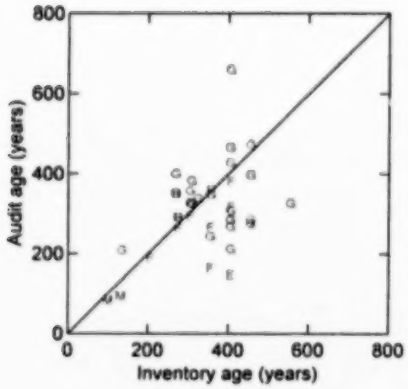

Figure 13: ***Age*** Audit (ground measured) age of top height trees versus inventory age, by inventory growth type group. Diagonal line represents a perfect correlation. (n=37)

Correlation coefficient: $r = 0.451$
(p-value = 0.005)

Mean audit age = 309 years
Mean inventory age = 342 years

Mean difference (audit age - inventory age) =
-33 years (p-value = 0.069)
95% confidence interval for mean difference:
-69 — 3

Figures 14 to 16 provide a graphical representation of the total bias, the model bias and the classification bias associated with the inventory volumes (using VDYP as the yield model) for the inoperable forested area. Figures 17 and 18 show the relationship between the audit and the inventory for the attributes of height and age respectively.

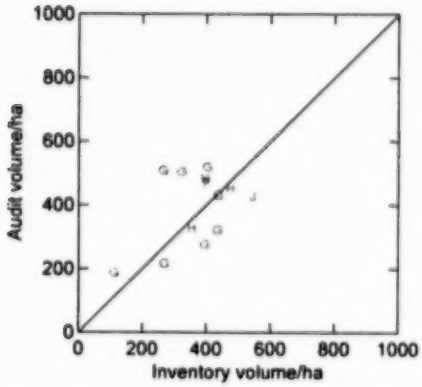

Figure 14: ***Total Bias for the Inoperable Forested Area*** Audit volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=13)

Correlation coefficient: $r = 0.470$
(p-value = 0.105)

Mean difference (audit volume - inventory volume)
= 24.5 m^3/ha (p-value = 0.459)
95% confidence interval for mean difference:
-45 — 94

Ratio of means = 1.07
95% confidence interval for ratio of means:
0.87 — 1.26

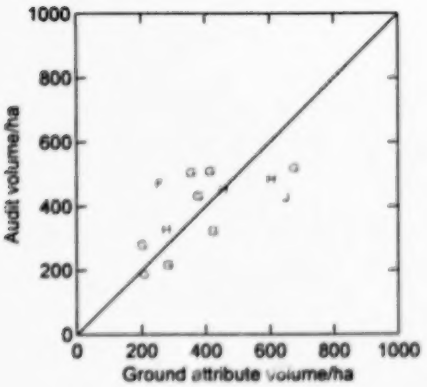

Figure 15: ***Model Bias for the Inoperable Forested Area*** Audit volume versus ground attribute volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=13)

Correlation coefficient: r = 0.629
(p-value = 0.021)

Mean difference (audit volume - ground attribute volume) = -4.02 m^3/ha (p-value = 0.911)
95% confidence interval for mean difference:
-80 — 72

Ratio of means = 0.99
95% confidence interval for ratio of means:
0.80 — 1.18

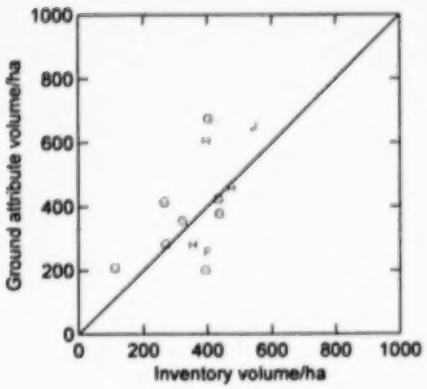

Figure 16: ***Classification Bias for the Inoperable Forested Area*** Ground attribute volume versus inventory volume, by inventory growth type group. Diagonal line represents a perfect correlation. (n=13)

Correlation coefficient: r = 0.562
(p-value = 0.046)

Mean difference (ground attribute volume - inventory volume) = 28.5 m^3/ha (p-value = 0.460)

Ratio of means = 1.08
95% confidence interval for ratio of means:
0.85 — 1.30

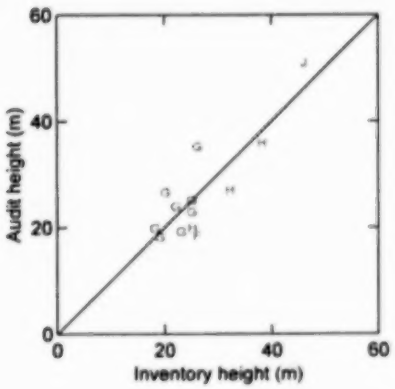

Figure 17: ***Height*** Audit (ground measured) top height versus inventory height, by inventory growth type group. Diagonal line represents a perfect correlation. (n=13)

Correlation coefficient: r = 0.850
(p-value < 0.001)

Mean audit height = 26.39 m
Mean inventory height = 26.67 m

Mean difference (audit height - inventory height) = -0.28 m (p-value = 0.844)
95% confidence interval for mean difference:
-3.27 — 2.72

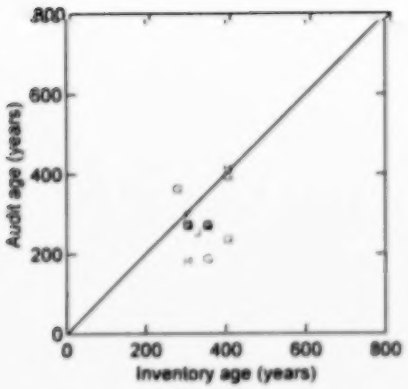

Figure 18: *Age* Audit (ground measured) age of top height trees versus inventory age, by inventory growth type group. Diagonal line represents a perfect correlation. (n=13)

Correlation coefficient: $r = 0.277$
(p-value = 0.360)

Mean audit age = 283 years
Mean inventory age = 343 years

Mean difference (audit age - inventory age) = -60 years (p-value = 0.010)
95% confidence interval for mean difference: -103 — -17

Analysis of mature species classification

The distribution of the growth type groups for the mature samples, as estimated by the inventory and by the audit, is provided in Table 12 (see Appendix D for a description of the species composition for each growth type group). Overall, 52% of the growth type groups assigned in the inventory matched the growth type group assigned in the audit.

Audit Growth Type Group	Inventory Growth Type Group						Total
	E	F	G	H	J	M	
E	***0***	0	0	0	0	0	0
F	0	***2***	9	1	0	1	13
G	0	7	***21***	3	0	0	31
H	0	0	2	***1***	0	0	3
J	0	0	0	0	***1***	0	2
M	0	0	0	0	0	***1***	1
Total	1	9	32	5	1	2	50

Table 12: Mature sample growth type group distribution for the audit and the inventory. The bold italic entries on the diagonal in the table indicate a growth type group match between the audit and the inventory.

A *K* statistic was used to compare the observed level of agreement (the proportion of growth type group matches) with the expected level of agreement. The calculated *Z*-value for the *K* statistic was 0.978. Since this value is less than the critical *Z*-value of 1.645 (at a 5% significance level), the *K* statistic indicated a poor level of agreement between the inventory growth type group classification and the audit classification. However, these results should be interpreted with care. The assessment of the mature inventory classification is based on broad species groupings (i.e. growth type groups). In addition, the sample sizes in the inventory audit are smaller than are usually recommended for application of the *K* statistic.

Analysis of immature inventory classification

Out of 20 stands sampled in the field, the inventory correctly identified site index within ±5 m of the audit site index for 11 stands; the inventory site index was more than 5 m lower than the audit site index for 8 stands, and more than 5 m higher for 1 stand. These results are illustrated in Figure 19 (see Appendix E for the immature sample data).

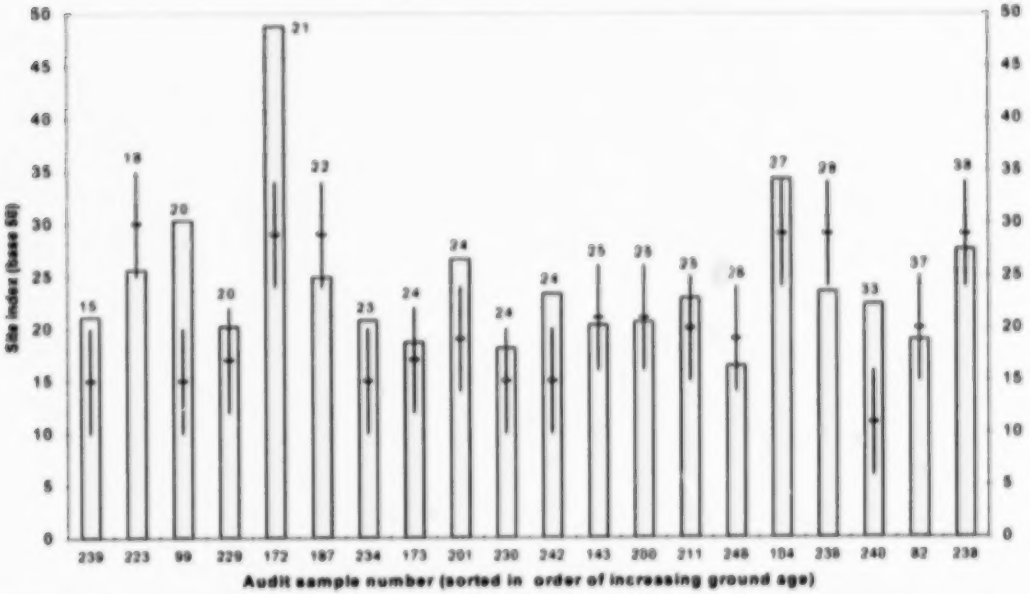

Figure 19: Comparison of audit and inventory site index values for immature stands. The shaded bars represent the audit site index. The tick marks on the vertical lines represent the inventory site index (the vertical lines have arbitrarily been set at ± 5 m around the inventory site index). The numbers on top of the bars correspond to the age, as estimated by the audit. The samples are sorted in order of increasing stand age, as estimated by the audit.

The distribution of the growth type groups for the 20 immature polygons, as estimated by the inventory and by the audit, is provided in Table 13. Overall, 60% of the growth type groups assigned in the inventory matched the growth type group assigned in the audit.

Audit Growth Type Group	Inventory Growth Type Group										Total
	F	G	H	J	L	M	N	O	P	Q	
F	***1***	2	0	0	0	0	0	0	0	0	3
G	1	***4***	0	0	0	0	0	0	0	0	5
H	0	0	***2***	0	0	0	0	0	0	0	2
J	0	0	0	***1***	0	0	0	0	0	0	1
L	0	0	0	0	***0***	1	0	0	0	0	1
M	0	0	0	0	0	***1***	0	0	0	0	1
N	0	0	0	0	1	0	***0***	0	0	0	1
O	0	1	0	0	0	0	0	***1***	0	1	2
P	0	0	0	0	0	0	0	0	***1***	0	1
Q	0	0	0	0	0	0	0	0	1	***1***	2
Total	2	7	2	1	1	2	0	1	2	2	20

Table 9: Immature sample growth type group distribution for the audit and the inventory. The bold italic entries on the diagonal in the table indicate a growth type group match between the audit and the inventory.

A *K* statistic was used to compare the observed level of agreement (the proportion of growth type group matches) with the expected level of agreement. The calculated *Z*-value for the *K* statistic was 5.853. Since this is greater than the critical *Z*-value of 1.645 (at a 5% significance level), the *K* statistic indicates a high level of agreement between the inventory growth type group classification and the audit classification. As was indicated for the mature inventory classification, these results should be viewed with care.

Analysis of non-forest inventory classification

Thirty stands classified as non-forest were assessed for their inventory assignment accuracy. The resulting score was 67%, which does not meet the provincial minimum standard of 85%.

Discussion and conclusions

The objective of the inventory audit in TFL 1 was to assess the overall accuracy of the current inventory. The mature, immature, and non-forest components were tested.

The results of the audit for the mature component of the inventory suggest that the analysis unit volumes have been over-estimated. When the data was post-stratified, a similar bias was observed in the operable forested area. There were some issues around what constituted an operable polygon, but even with a more conservative definition, the trends remained the same.

However, additional analyses that examined the accuracy of the inventory using the VDYP yield model and the current inventory attributes did not show the same volume over-estimation bias that was apparent for the analysis unit volumes in TFL 1. Using VDYP and the current TFL 1 inventory attributes produced statistically acceptable inventory volumes.

Audit results for the immature component of the inventory suggest an acceptable level of accuracy for site index assignment in young stands. However, it should be noted

that the low inventory site index assignment in 8 of the sample stands appears to be due to a potential under-estimation of regenerated stand heights.

The audit assessment of the non-forest classification in this TFL indicates that it did not meet provincial standards. Anomalies in the non-forest classification were observed due to poor stratification of height class 1 and 2 forested stands within alpine and snow slide areas. Results indicate that the issue of non-forest classification accuracy in this TFL has no impact on the forested area available for timber harvesting reported in the timber supply analysis.

References

Cohen 1960. A coefficient of agreement for nominal scales. **Educational and Psychological Measurement**, 20(1):37-46.

Walpole 1974. **Introduction to Statistics**. 2nd edition. MacMillan Publishing Co. Inc., New York. 340pp.

Appendices

A Mature Sample Data

B Data for the Operable Subset of Mature Samples

C Data for the Inoperable Subset of Mature Samples

D Species Composition by Growth Type Group

E Immature Sample Data

A Mature Sample Data

B Data for the Operable Subset of Mature Samples

C Data for the Inoperable Subset of Mature Samples

D Species Composition by Growth Type Group

Growth Type Group Letter Code	Growth Type Group Species Composition
A	Fd, FdDecid
B	FdCw and FdYc, FdH, FdS
C	FdPl, FdPy, Py
D	FdL, Pw, LFd, L
E	Cw or Yc, CwFd, CwL, CwPy, CwPw, CwPl, CwDecid, CwH
F	H, H Decid.
G	HFd, HL, HPy, HPw, HPl, HCw, HB, HS
H	B, BH, BS, BFd, BPw, BPl, BL, BPy, BDecid
I	S
J	SFd, SL, SPw, SPy, SH, SCw, SYc, SB
K	SPl, S Decid.
L	Pl or Pa
M	Pl Fd, PlPy, PlL, PlPw, PlS, PlB, PlH, PlCw, PlYc
N	Pl Decid.
O	D Conif., At Conif.
P	Dr Decid., Mb, E, At Decid.
Q	Ac Conif., Ac Decid.

E Immature Sample Data

Glossary

accuracy: A measure of the closeness of an estimate to the true value.

allowable annual cut: The rate of timber harvesting specified for an area of land.

analysis unit: The basic building block around which inventory data and other information are assembled for use in forest planning models. Analysis units represent the general level of aggregation, or detail, at which a timber supply analysis is carried out. They are normally defined by tree species and site qualities.

bias: The quality of a measurement device or procedures that tends to result in a systematic misrepresentation of what is being measured.

coefficient of variation: A relative measure of the variation of the population calculated as the ratio between the standard deviation and the mean value.

confidence interval: The range of values within which the population parameter is expected to lie.

confidence level: The stated probability that a population parameter lies within a given confidence interval.

correlation coefficient: A measure of the linear relationship between two variables. A value of 0 for the correlation coefficient indicates a random relationship whereas a value of ±1 indicates a perfect positive or negative linear correspondence.

diameter at breast height (dbh): The stem diameter (outside-bark) of a tree measured at breast height (1.3 metres above the point of germination) to the nearest millimetre.

field visitations: Ground level field procedures designed to provide physical verification of polygon inventory attributes.

free growing (crop): A crop of healthy trees of a commercially valuable species, the growth of which is not impeded by competition from plants, shrubs or other trees.

inoperable: Refers to areas having merchantable timber that cannot be harvested economically using current harvesting technology because of some physical barrier (such as a hanging valley), and to areas containing small patches of overmature timber surrounded by large areas of young stands.

***K* statistic:** A test for statistical significance of agreement between nominal scale data. The *K* statistic is calculated as *(actual accuracy - expected accuracy) / (1-expected accuracy)*. The actual accuracy is estimated from the diagonal totals, and expected accuracy is estimated from the marginal totals, from the matrix of similarity (e.g. a matrix of audit and inventory GTGs). The value of *K* is 1 when all elements are on the diagonal (i.e. perfect agreement), and less than 1 otherwise.

mean: The average value of a set of observations.

***p*-value:** The probability associated with the result of a statistical test (e.g. test of significant difference). The *p*-value represents the level of significance for the test; the smaller the value of this probability, the heavier the weight of the sample evidence.

pre-inventory assessments: Pre-inventory analyses are inventory activities to evaluate the existing forest inventory as the basis for deciding whether to re-inventory or update the current inventory, and to document the existing inventory, maps, and photos to support the execution of the reinventory or update if required.

ratio estimate: The ratio between two different estimates.

representative: The quality of a sample having the same characteristics as the population from which it is selected.

sampling: The process of selecting observations from a population.

sampling error: The error attributed to sampling procedures. It is computed as the standard error of an estimate multiplied by a value from the t distribution corresponding to a stated confidence level. Sampling error is often expressed as a percentage of the estimate (e.g. percentage of the mean).

significant difference: An expression used in reference to the results of a statistical test in which either two or more estimates are compared or an estimate is compared to a fixed value. If the observed difference is greater than what might be expected as a chance occurrence due to the sampling procedures, the difference is said to be statistically significant.

site index: A measure of site productivity. Site indices are based on tree height as a function of stand age and are usually expressed graphically as site index curves. A number of site index curves have been developed for British Columbia's major commercial tree species.

standard error: An expression of the absolute variability of an estimate. It is computed as the standard deviation divided by the square root of the number of samples.

standard deviation: A measure of the absolute variation of the population.

timber supply analysis: The technical process of amalgamating land management information into computer systems that predict the amount of timber available for harvest over given time periods.

timber supply area: An integrated resource management unit established in accordance with section 6 of the *Forest Act*.

tree farm license: An integrated resource management unit established in accordance with section 28 of the *Forest Act*.